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amb

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ABSTRACT

from pg 1

Results

~~This report presents the results of work accomplished on contract N62269-67-C-0180, Feasibility Study of the CH-53A Horizontal Stabilizer as an HF antenna. Ground tests, conducted on a Bailed CH-53A BuNo. 152396,~~ indicate that performance of the HF communication system with an isolated stabilizer antenna provides an improved communications capability for the CH-53A helicopter.

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INTRODUCTION

This report presents the results of work accomplished ~~under contract N62269-67-C-0190, from the U. S. Naval Air Development Center, Johnsville, Pa.,~~ to investigate the feasibility of using the horizontal stabilizer of the CH-53A as an HF antenna. Ground tests were conducted to establish the ability of the horizontal stabilizer to provide an improved HF communications system for the CH-53A helicopter; the present fixed wire antenna was used as basis for the comparison. The present fixed wire antenna is approximately 32 ft in length and is installed on the fuselage starboard side. Performance of the horizontal stabilizer with the Univac 3461-A1 coupler was compared to the fixed wire antenna and CU-351/AR antenna coupler, both antenna systems operating with the same AN/ARC-94 transceiver. The Univac 3461-A1 HF antenna coupler and the CU-351/AR antenna coupler were supplied as GFAE to Sikorsky Aircraft for tests conducted under this contract. To preclude introduction of undesirable variables associated with the results of tests which are conducted on a mock-up, the ground tests for this study were conducted on a standard production CH-53A helicopter, BuNo. 152396, which was bailed to Sikorsky Aircraft for the tests reported herein.

to page ii

1. Preliminary Design

Prior to start of design of the test horizontal stabilizer, the literature was reviewed and new sources of information were sought. The investigation of prior work did not provide any definitive design data. Each instance of design of an isolated portion of an airframe as an HF antenna is a particular case.

Design of the feasibility stabilizer was based on the following factors:

(a) The structural design criteria for the CH-53A horizontal stabilizer.

(b) Providing a reactive impedance component of the isolated section which was within the matching capability of a typical HF antenna tuning unit (HF coupler), with particular consideration of the Univac Type 3461 coupler. This design factor is controlled by the physical gap dimensions of the isolated section and the adjacent airframe structure and the dielectric constant of the insulating material in the gap. It is apparent that the physical gap dimensions are also relevant to design factors of voltage breakdown and corona discharge characteristics. To enhance HF system performance at 2 Mhz, a design objective of 500 to 600 ohms capacitance reactance was established.

(c) Providing a resistive component of impedance compatible for operation with the Univac 3461 and other typical HF couplers. A design objective was established to provide a minimum total resistive component of 3 ohms. Thus, an isolated stabilizer section with the largest possible length was used.

Prior to construction of the test stabilizer, the calculated impedance of the isolated section was validated by impedance measurements on a simple sheet metal box with the approximate dimensions of the horizontal stabilizer. The tests were made to confirm analytical calculations and the results are as follows:

(a) The resistive component of impedance increased linearly with an increase in width of the insulating gap and with an increase of length of the isolated element (stabilizer).

(b) The capacitive component of impedance increased linearly as the insulating gap width was increased, or as the length of the isolated element was decreased.

Based on the above results and on the design objective values of impedance, design of a test stabilizer as shown in Figure 2 was completed and the test article was constructed.

2. Construction

(a) Horizontal Stabilizer

The horizontal stabilizer portion of a wooden, full scale, mock-up of the complete CH-53A tail assembly was utilized, with prior approval of the NAVAIRSYSPLANT representative at Sikorsky Aircraft. Examination of the mock-up stabilizer showed it was approximately four inches shorter than the actual helicopter stabilizer but was dimensionally identical in all other respects. Thus, by adding the 3 inches of dielectric gap material, the test stabilizer was similar to the production CH-53A stabilizer, but 1 inch shorter in length.

The test stabilizer was covered with a 16 gage, one sixteenth inch mesh, copper screen to provide a conductive surface similar to the aircraft skin. Figures 2, 3, and 4 show the details of the construction and screening. To provide a good electrical feed connection to the isolated section, a 0.020 inch thick copper patch was soldered on to the underside. This connection strip, shown in Figure 5, provided a direct, short, connection to the RF output terminal of the Univac antenna coupler and to the impedance bridge.

(b) Dielectric Gap

An epoxy glass laminate processed at Sikorsky Aircraft in accord with Reference (3) and Reference (6) was selected for the 3 inch gap between the root and isolated outboard section of the horizontal stabilizer. This epoxy laminate dielectric exceeds the mechanical requirements of Reference (2) and provides satisfactory electrical characteristics. The material has a dielectric constant of approximately 4.5, dissipation factor of 0.0184 and a dielectric strength of approximately 340 volts per mil. Thus, voltage breakdown due to dielectric failure across the 3 inch gap is not expected to occur and internal heating due to dielectric losses are minimal. A sample calculation of dielectric losses is presented in Appendix I.

As shown in Figures 3 and 4, the isolated section of the stabilizer was physically supported by 4 load bearing dielectric beams. An additional volume of dielectric was placed in the gap, for the feasibility tests, to simulate the material required in the gap for an airworthy horizontal stabilizer. Thus, the performance data reported herein is for an isolated stabilizer with a 3 inch gap; the gap being dielectric loaded to provide the total volume of dielectric material required to meet structural and aerodynamic design requirements for a flyable horizontal stabilizer.

(c) Equipment Rack

A rack was constructed to hold the required test equipment, see Figures 5 and 6, and the Univac coupler. A 0.020 inch thick copper sheet four inches wide was used to provide a satisfactory ground for all of the test equipment. The lower shelf was removed after the impedance measurements were completed and the Univac 3461-A1 Antenna Coupler was mounted on the top shelf; the RF output terminal was then connected directly to the isolated stabilizer section by a direct copper conductor.

3. Pre-Installation Measurements

(a) Extension Cable

The Univac antenna coupler was installed immediately below the horizontal stabilizer root, adjacent to the vertical tail pylon. This location of the coupler required an extension cable, for connection to existing CH-53A wiring. As stated by Collins Radio, Reference (3), the maximum resistance between the 28 VDC output of the RT-618/ARC-94 and the 28 VDC input of the CU-351/AR must be less than 1.0 ohms. The resistance between these two points was measured with a Wheatstone bridge and found to be 0.487 ohms. Univac has published no resistance requirement for their 3461-A1 Antenna Coupler, but it was decided to retain the Collins requirement. A 16 AWG wire was used in the extension cable harness to meet the maximum resistance requirement.

(b) Bonding

The resistance from the feedpoint to various points of the active portion of the stabilizer was measured with the Wheatstone bridge and found to be between 0.002 and 0.005 ohms.

4. Ground Tests

(a) Bonding

The stabilizer was mounted on the bailed aircraft and a test was made of the bonding between the root end of the stabilizer and the top of the tail pylon. The resistance was found to be 0.0036 ohms. In addition, a resistance check was also made from the top of the tail pylon to the main section of the airframe through the tail pylon hinge point. The resistance was 0.0076 ohms.

(b) Impedance

The equipment was set up as shown in Figures 5 and 6 to take impedance measurements. Before starting the complete set of impedance measurements, a preliminary check was made at 30 Mhz. A clear and definite null on the impedance bridge indicated that the set-up was satisfactorily grounded. The complete set of impedance readings was then taken. The results are presented in Table I and are plotted in Figure 1. The resistive component of the impedance at 2 Mhz is relatively high compared to values normally obtained from a fixed wire antenna.

(c) VSWR and RF Current

(1) The equipment required for the impedance measurements was removed from the rack and the lower shelf of the rack was removed. The Univac 3461-A1 Antenna Coupler and rack mount were installed on the upper shelf. The same copper grounding sheet was used throughout the remainder of the tests.

(2) A RF Ammeter was installed between the RF output terminal of the coupler and the feedpoint of the stabilizer. Forward and reflected power was measured at the RF output terminal of the RT-648/ARC-94 transceiver.

(3) The H. F. system was tuned to each frequency and the Univac coupler was allowed to tune the impedance of the horizontal stabilizer. The transceiver was then keyed with no modulation while the power meter and the RF Ammeter readings were recorded. The RF Ammeter was read from the ground with a high power telescope to reduce undesired variation of the impedance caused by personnel close to the stabilizer. The data obtained is presented in Table 2. This data shows that the rated

operating current and voltage limits of the antenna coupler-transceiver combination are not exceeded and that the antenna coupler is capable of providing a good VSWR match of the isolated stabilizer to the transceiver.

(d) Antenna Coupler Efficiency

The calculated power transfer efficiency between the power source (transmitter) and the load (isolated stabilizer as an antenna), using an efficiency formula supplied by Univac for the Type 3461-A1 antenna coupler are presented in Table 12. Univac performed bench efficiency tests of the 3461-A1 using the measured impedance values of the isolated stabilizer simulated by a dummy load. The bench test measurement set-up is shown in Figure 7 and the results are presented in Table 3 and Figure 8.

(e) Field Intensity

Measurement of the radiated field intensity over the 2 to 30 Mhz frequency spectrum for each cardinal heading were performed at distances of two hundred and two thousand feet. The results are presented in Tables 4 through 11 and Figure 9shows the test site. It is noted that a simultaneous recording of field intensity was made at both the distances; this simultaneous recording minimized errors due to relative bearing of the aircraft and the recording points and also minimized variations due to possible changes of propagation constants in the transmission path. In addition, the field intensity readings for the four cardinal headings were obtained by successively rotating the helicopter through 90 degrees; the 2 recording points (200 and 2000ft) were always at the same location. This recording method was followed for both the fixed wire reference antenna and for the isolated stabilizer, thus further reducing possible variations due to propagation changes and providing a sound basis for a comparison of the relative performance of the test (stabilizer) and reference (fixed wire) antennas.

To provide a clear picture of the relative performance of the isolated stabilizer and fixed wire antennas, Figures 10 through 17 show direct plots of the isolated stabilizer field intensity in decibels above or below the reference fixed wire antenna. The zero db line represents equal field intensity recorded from both antenna systems. Positive or negative db represents field intensity levels for the isolated stabilizer/Univac coupler combination above or below values recorded for the fixed wire and CU-341/AR coupler combination. The plots, Figures 10 through 17, are based directly on the microvolt per meter values recorded in Tables 4 through 11, and are presented for both vertical and horizontally polarized field intensities observed at 200 and 2000 ft for the 4 cardinal headings.

(f) Rotor Modulation

The presence of rotor modulation effects for the isolated stabilizer as an HF antenna were investigated. The two tests performed did not show evidence of any observable effects due to the main or tail rotor of the CH-53A helicopter.

The first test was to determine a possible variation of impedance of the isolated stabilizer as one of the main rotor blades was manually turned thru an arc close to the stabilizer. During this test, made at a frequency of 8.6 Mhz, the impedance bridge null was closely monitored and no observable change in impedance was discerned.

Secondly, a communications check was made during ground-run with rotors turning. At frequencies of 3.281 and 9.011 Mhz the HF system, consisting of AN/ARC-94 transceiver, Univac 3461-A1 coupler and the isolated stabilizer antenna, was operated. The ground monitor station used a field intensity meter approximately 1000 ft distant from the helicopter. As the aircraft was turned thru 360°, radio transmissions at the 2 test frequencies were monitored. No observable effects due to rotor modulation were noted. Reception of the voice modulated transmission from the helicopter HF system were clear and uninterrupted.

5. Results and Conclusions

(a) Bonding

Based on the measured values of resistance between the copper mesh covered root of the horizontal stabilizer to the vertical tail pylon and to the main fuselage, the test set-up met the CH-53A bonding requirements specified in Reference (4). The bonding was typical of that expected for a production aircraft.

(b) Impedance

The impedance exhibited by the isolated stabilizer, constructed for this study, is presented in Table 1 and Figure 1. The impedance is compatible for satisfactory operation of the Univac Type 3461-A1 antenna coupler. For the ground tests conducted during this study, no failure or malfunction of the Univac coupler was observed due to values of or variations in impedance.

In addition to consideration of the impedance of the isolated stabilizer for compatible operation with the Univac 3461-A1, it is considered that the impedance exhibited is satisfactory for compatible operation with other typical HF antenna couplers. It is noted that the test stabilizer displayed an impedance characteristic curve which resembles closely that of the DC-4 Tail Cap H. F. Antenna discussed in Reference (5).

(c) VSWR and RF Current

The recorded values of forward and reflected power and feedpoint current, with calculated VSWR values, are presented in Table 2. The VSWR values at all frequencies tested was within the limits specified, Reference (6), for satisfactory operation of the AN/ARC-94 HF transceiver. Table 2 also shows that the maximum current rating of 7 amps for the Univac 3461-A1 coupler was not exceeded and calculated worst case voltage condition at the coupler output terminal does not exceed the specified 10 KV maximum rating.

It is concluded that for the isolated stabilizer and Univac 3461-A1 coupler combination, VSWR values are satisfactory for operation of the AN/ARC-94 transceiver and voltage or current limits specified for the 3461-A1 coupler are not exceeded.

(d) Antenna Coupler Efficiency

The efficiency of the Univac 3461-A1 antenna coupler, based on bench tests of the coupler working into a dummy load simulating the impedance of the isolated stabilizer is presented in Table 3. The efficiency varies from 38% at 2 Mhz to above 90% at frequencies of 18 Mhz and above. These efficiencies are considered satisfactory for operation of the AN/ARC-94 HF Radio, with an isolated stabilizer antenna, on the CH-53A helicopter.

(e) Field Intensity

(1) Radiation of vertically polarized energy by the stabilizer is equal to or better than radiation of the fixed wire, except at the 90° heading for frequencies below 5.3 Mhz. This conclusion is based on the general trends seen in Figure 10 through 13, for data taken at 2000 feet.

(2) As shown in Figures 14 through 17, radiation of horizontally polarized energy from the isolated stabilizer shows a general trend of being superior to the fixed wire for frequencies below 8 Mhz and above 18 Mhz. For a band of frequencies between 8 and 18 Mhz, the fixed wire is apparently a more efficient radiator than the stabilizer.

(3) Based on the above considerations regarding the relative performance of the isolated stabilizer and the fixed wire combinations, it is concluded that, in general, the isolated stabilizer is a more efficient HF radiator.

(4) Bench tests were conducted to determine differences in efficiency of the 3461-A1 and CU351/AR antenna couplers, since the apparent superiority in radiation capability of the isolated stabilizer/Univac coupler combination could be due to differences in efficiency of the two couplers. For the tests conducted on both couplers operating into the same impedance values at frequencies between 2 and 6 Mhz, the efficiencies did not differ by greater than 3%. Therefore, it is concluded that the greater field intensities from the stabilizer/Univac coupler are attributable to the more efficient radiation capability of the stabilizer as compared to the fixed wire.

(f) Rotor Modulation

As reported in Section 4(f) of this report, limited tests were conducted to determine possible rotor modulation effects. Both methods of test; i.e., impedance variation with rotor blade passage and actual communications tests are valid criteria for determination of rotor modulation. On the basis of the tests performed, undesirable rotor modulation effects are not expected when an isolated stabilizer is utilized as the HF antenna for the CH-53A helicopter.

RECOMMENDATIONS

Based on the results of this feasibility study, it is recommended that a follow-on prototype test program be initiated. Since the study reported herein only included ground tests, the objectives of the follow-on prototype test program should be as follows:

(a) To establish the flight performance of a prototype test isolated stabilizer and its capability to provide an improved HF communications system for the CH-53A helicopter.

(b) While conducting the electrical performance tests for (a) above, utilize the flight test article to obtain structural design data which can be used for subsequent production design and incorporation.

LIST OF FIGURES

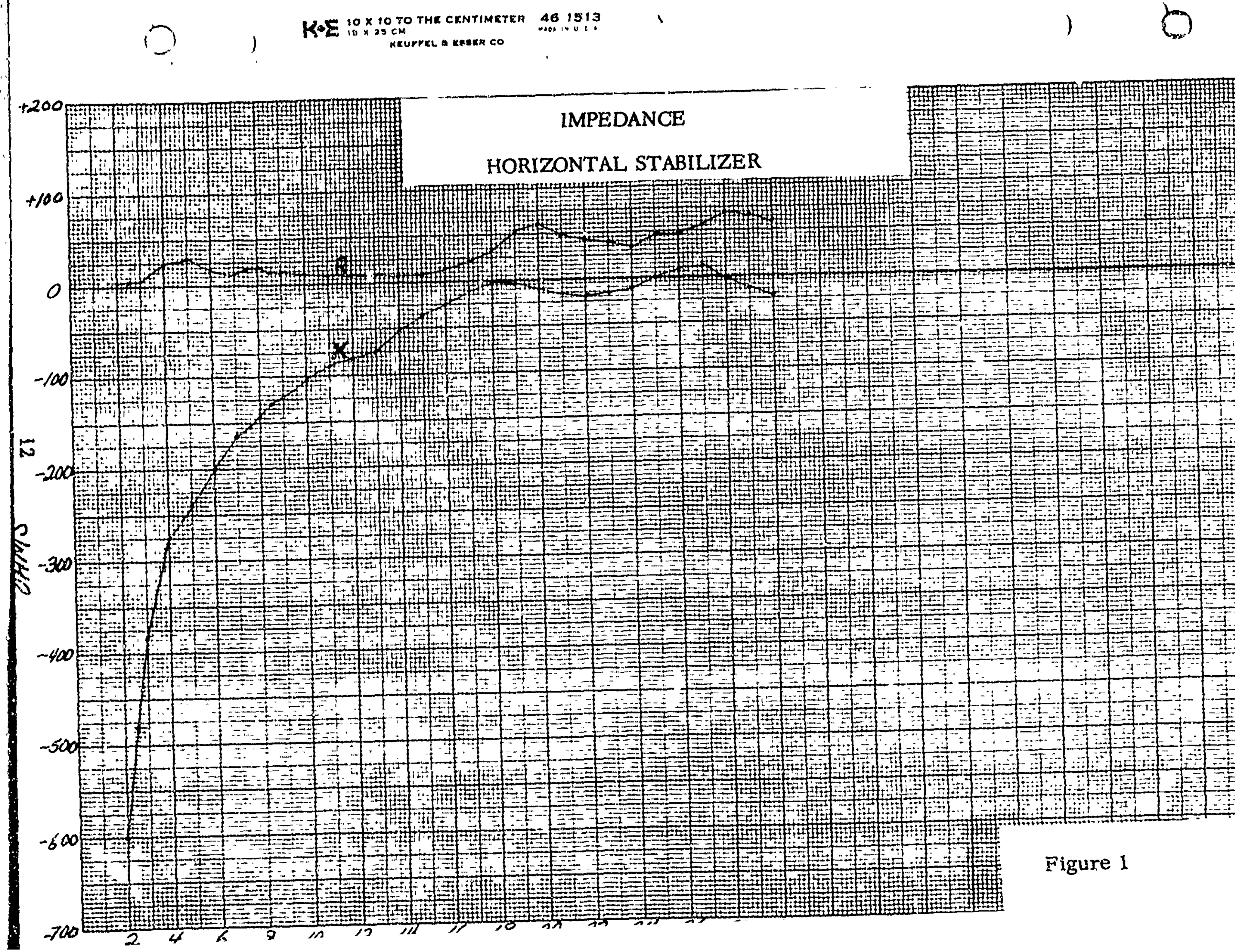

K+E 10 X 10 TO THE CENTIMETER 46 1513
10 X 25 CM
KEUFFEL & ESSER CO
IMPEDANCE
HORIZONTAL STABILIZER
+200
+100
0
-100
-200
-300
-400
-500
-600
-700
OHMS
R
X
2
4
6
8
10
12
14
16
18
20

Figure 1

CH-53A HORIZ. STAB. ANTENNA FOR FEASIBILITY STUDY

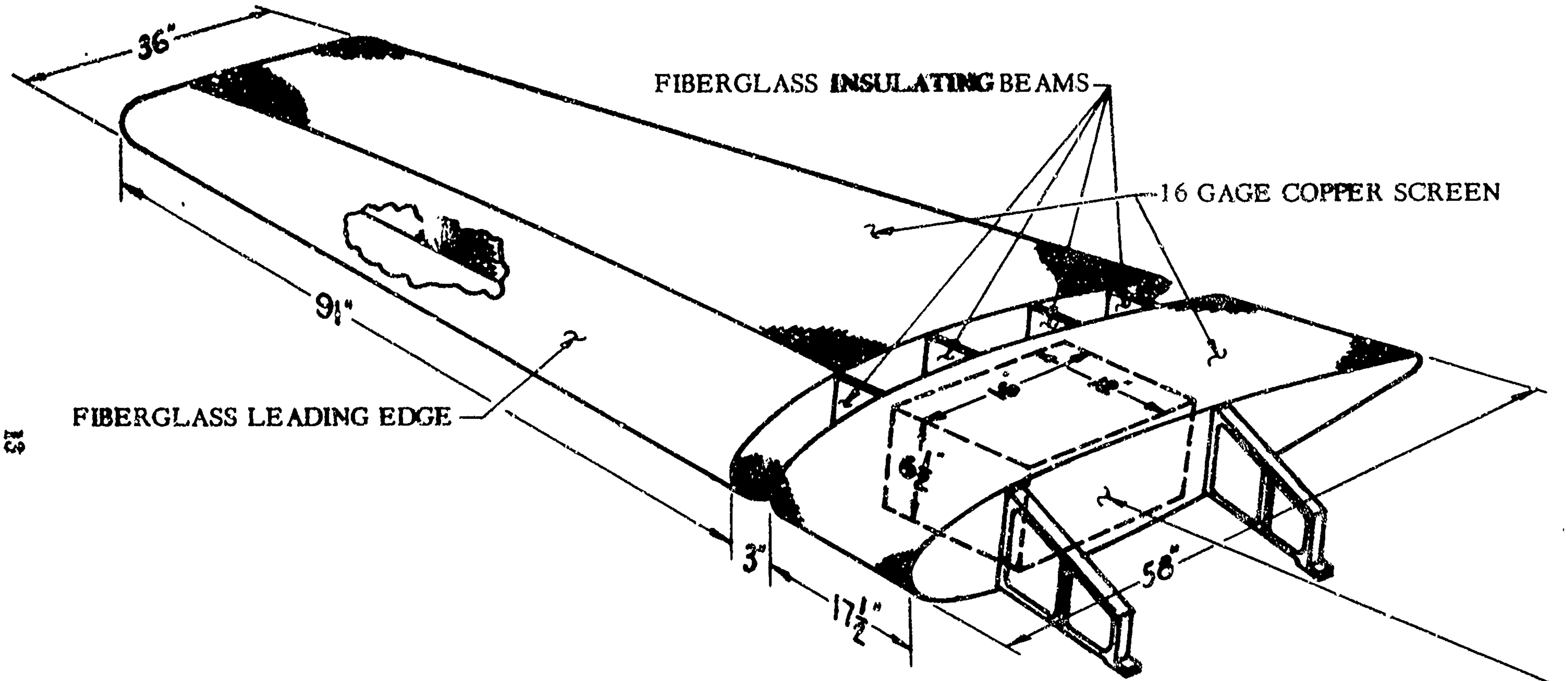


FIGURE 2

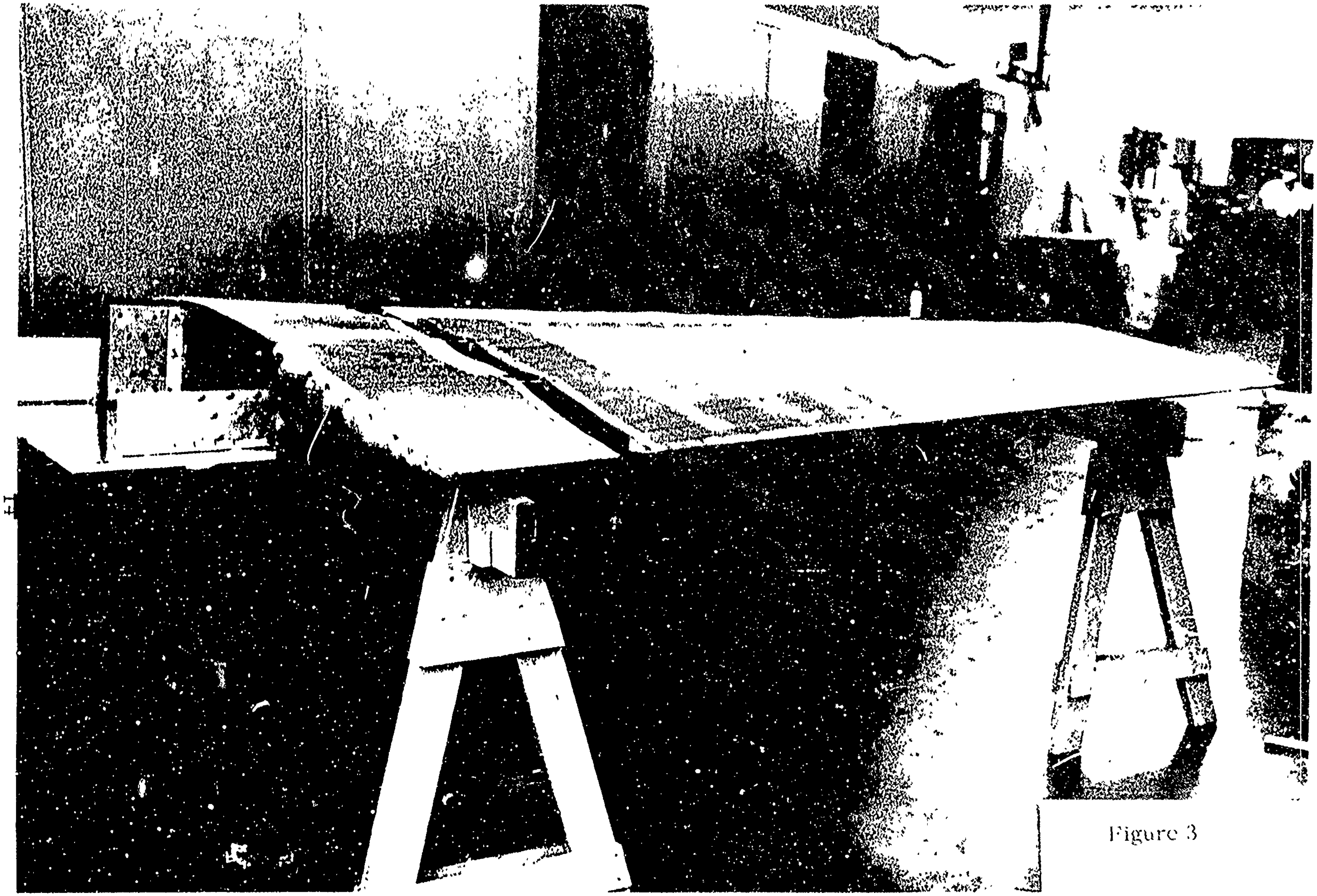


Figure 3

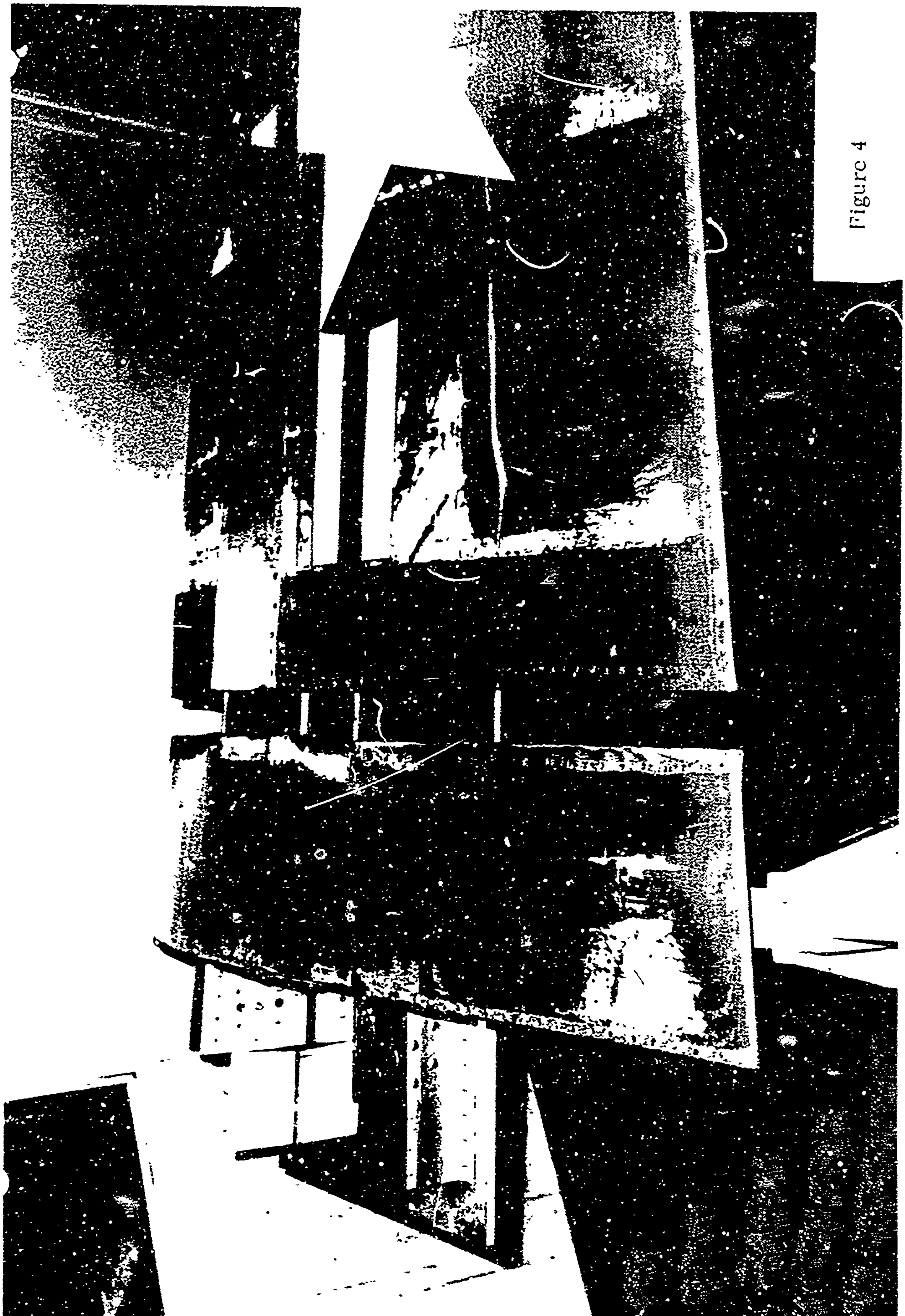


Figure 4

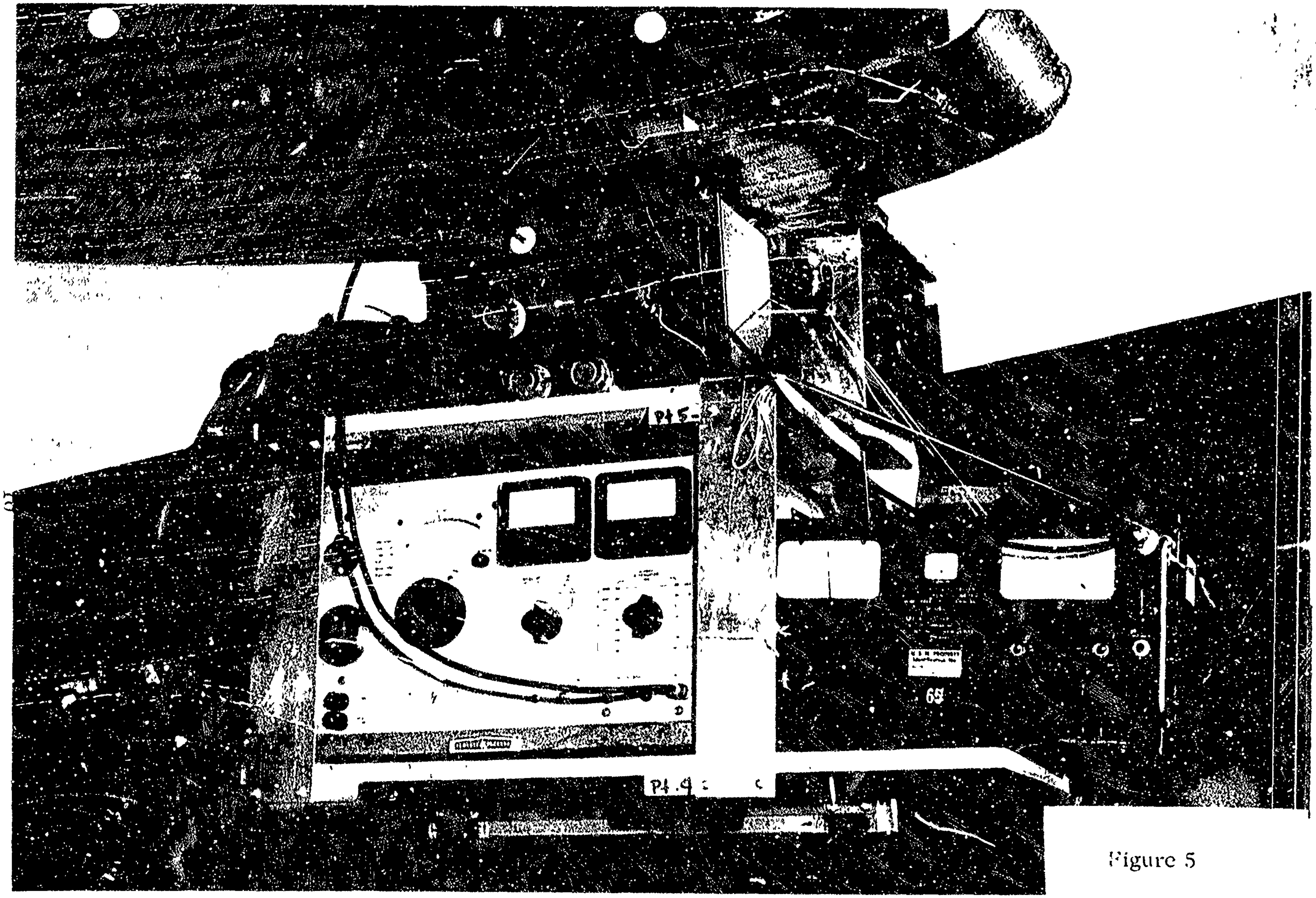


Figure 5

S-48001 CH-53A HORIZONTAL STABILIZER ANTENNA SHOWING IMPEDENCE MEASURING EQUIPMENT AND SET-UP.
1-16-67

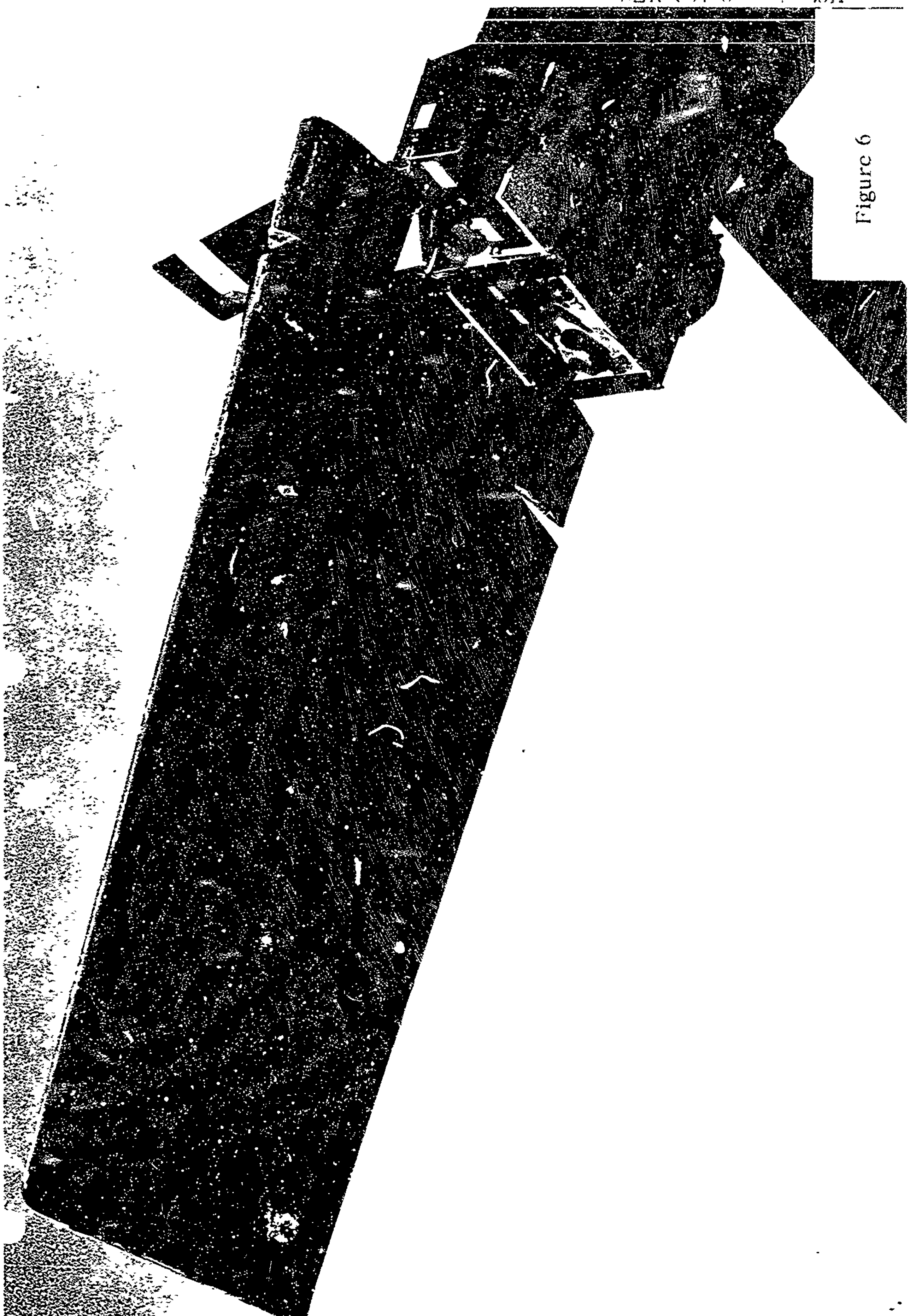
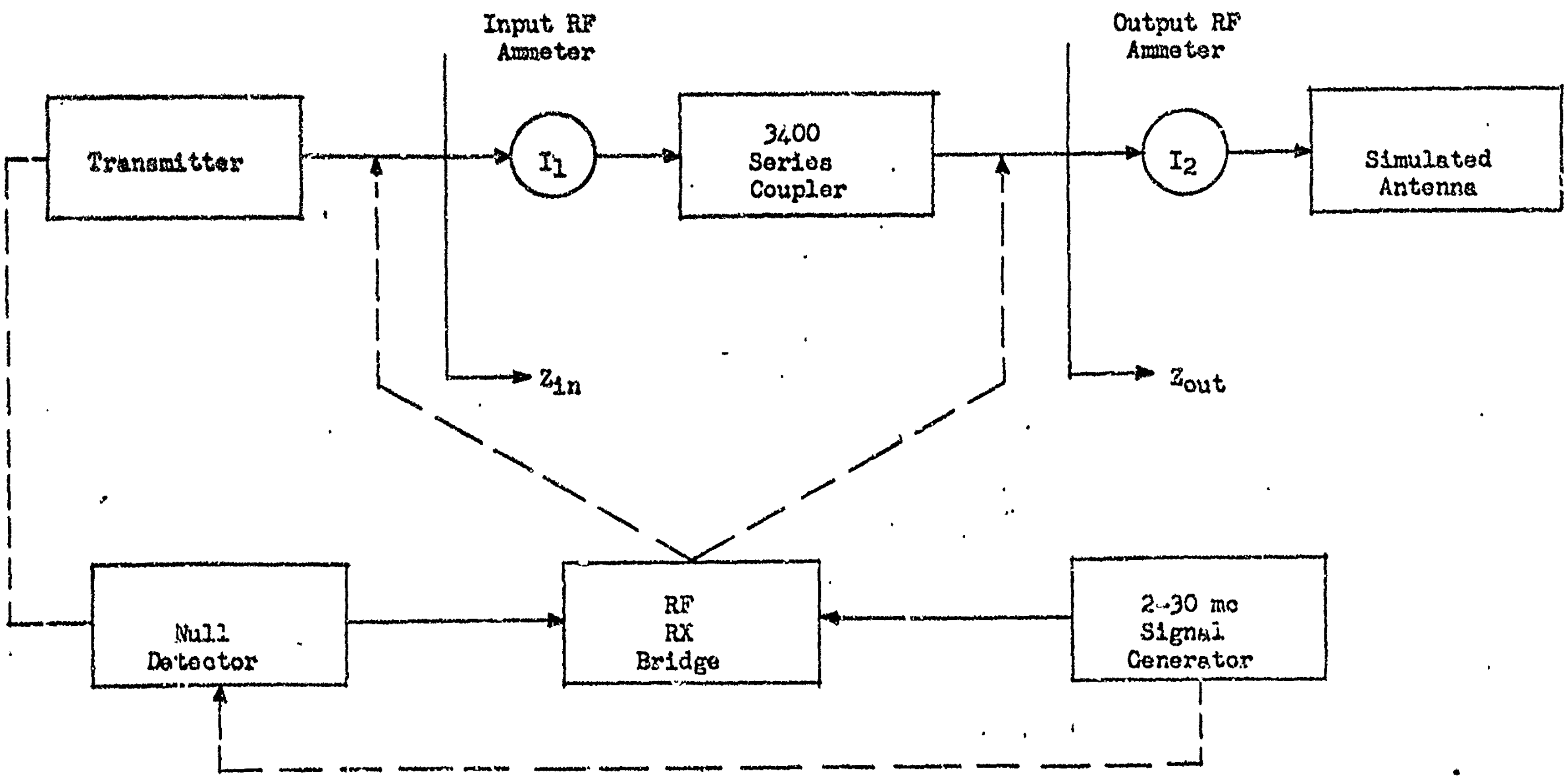


Figure 6

S-II 000 CH-53A HORIZONTAL STABILIZER ANTENNA INSTALLATION AND EQUIPMENT RACK. 1-16-67



SAMPLE DATA

Frequency	Z_{in}	VSWR	I_1	Power in	Z_{out}	I_2	Power out	Efficiency
6 mc	46 - j7	1.16	1.8	149	17 - j200	2.7	123	83.1%

FIGURE 7

Efficiency Test Set-Up

UNIVAC 3461-A1 ANTENNA COUPLER
EFFICIENCY

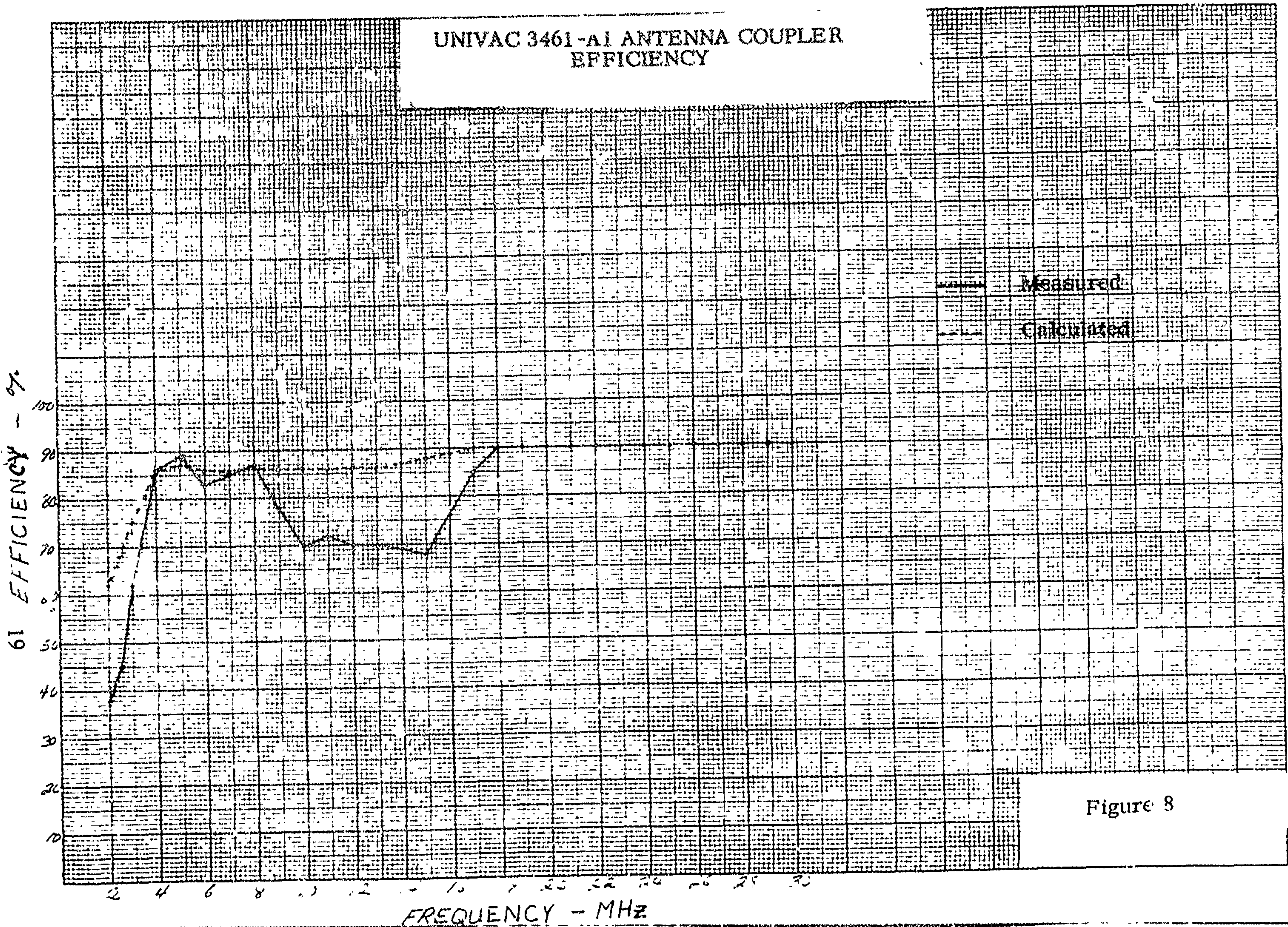


Figure 8

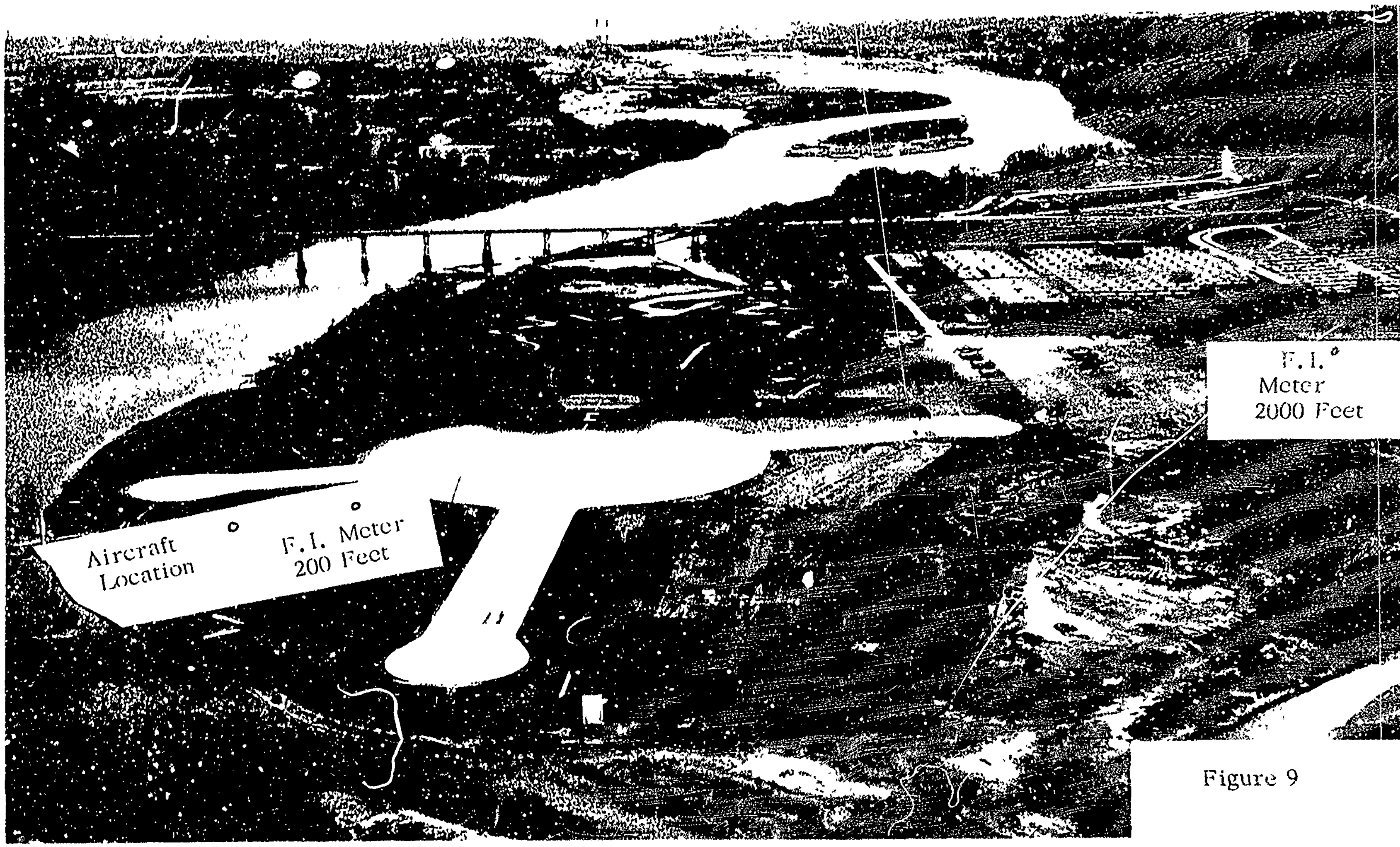


Figure 9

S-34392 A

CH-53A HORIZ. STAB. HF ANTENNA
FEASIBILITY STUDY TEST SITE

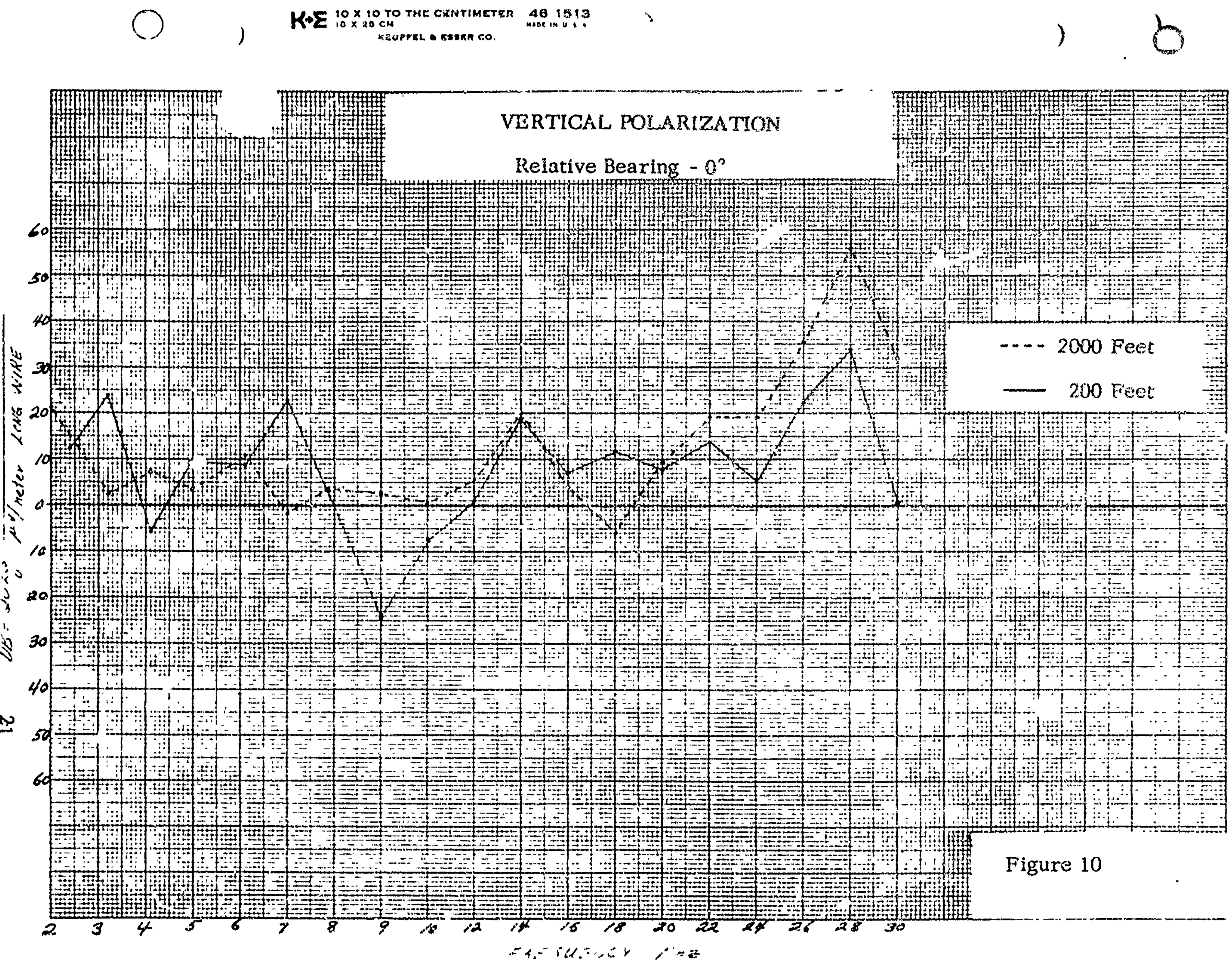

K+E 10 X 10 TO THE CENTIMETER 46 1513
10 X 25 CM
MADE IN U.S.A.
KEUFFEL & ESSER CO.
VERTICAL POLARIZATION
Relative Bearing - 0°
2000 Feet
200 Feet
60
50
40
30
20
10
0
10
20
30
40
50
60
2
3
4
5
6
7
8
9
10
12
14
16
18
20
22
24
26
28
30

Figure 10

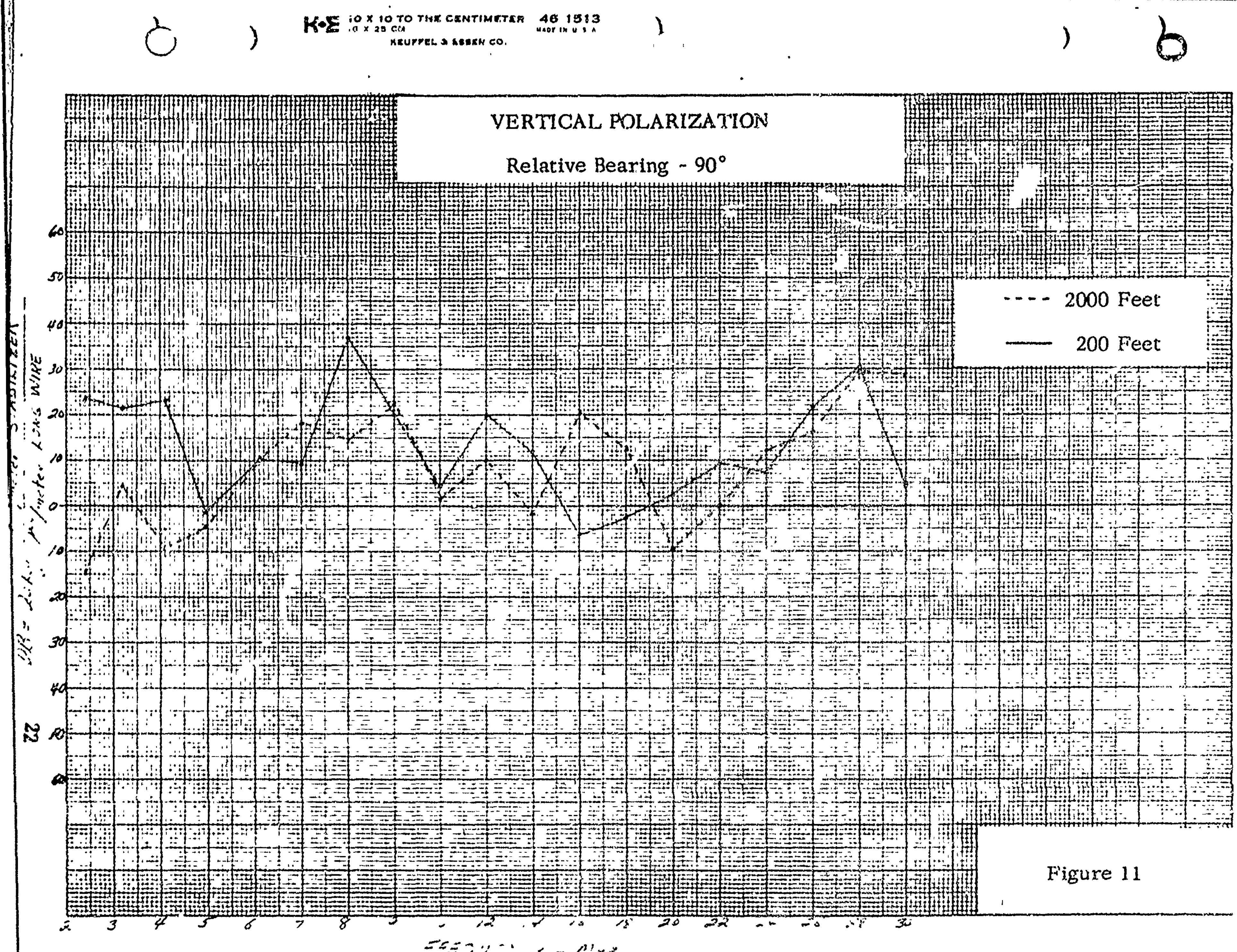

K•E 10 X 10 TO THE CENTIMETER 46 1513
10 X 25 CM MADE IN U.S.A.
KEUFFEL & ESSER CO.
VERTICAL POLARIZATION
Relative Bearing - 90°
2000 Feet
200 Feet
60
50
40
30
20
10
0
10
20
30
40
3
4
5
6
7
8
12
20
22

Figure 11

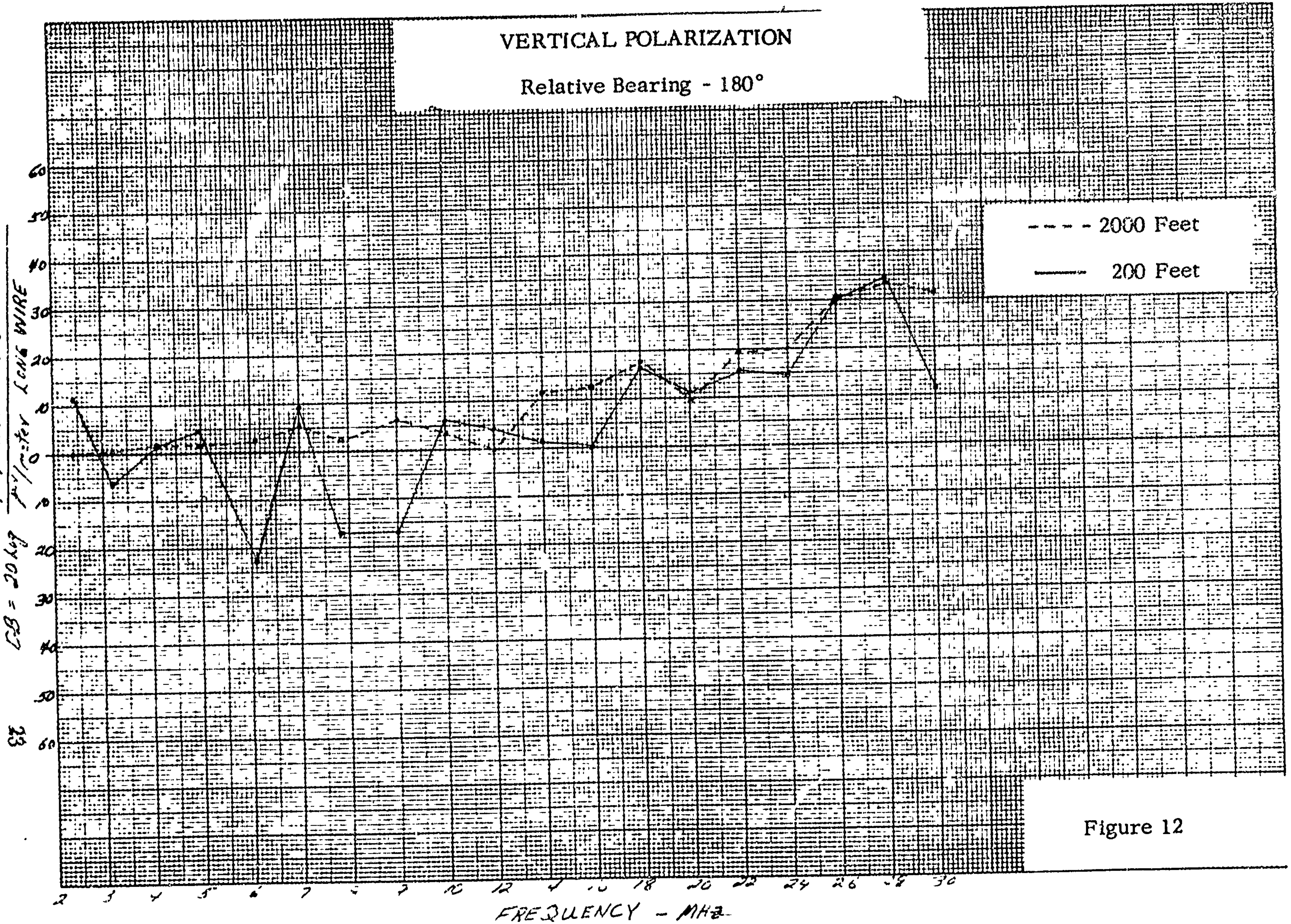

VERTICAL POLARIZATION
Relative Bearing - 180°
- - - - 2000 Feet
——— 200 Feet
60
50
40
30
20
10
0
10
20
30
40
50
60
2
3
4
5
6
7
10
12
18
20
22
24
26
30
FREQUENCY - MHz
CB = 20kg
1/meter LONG WIRE

Figure 12

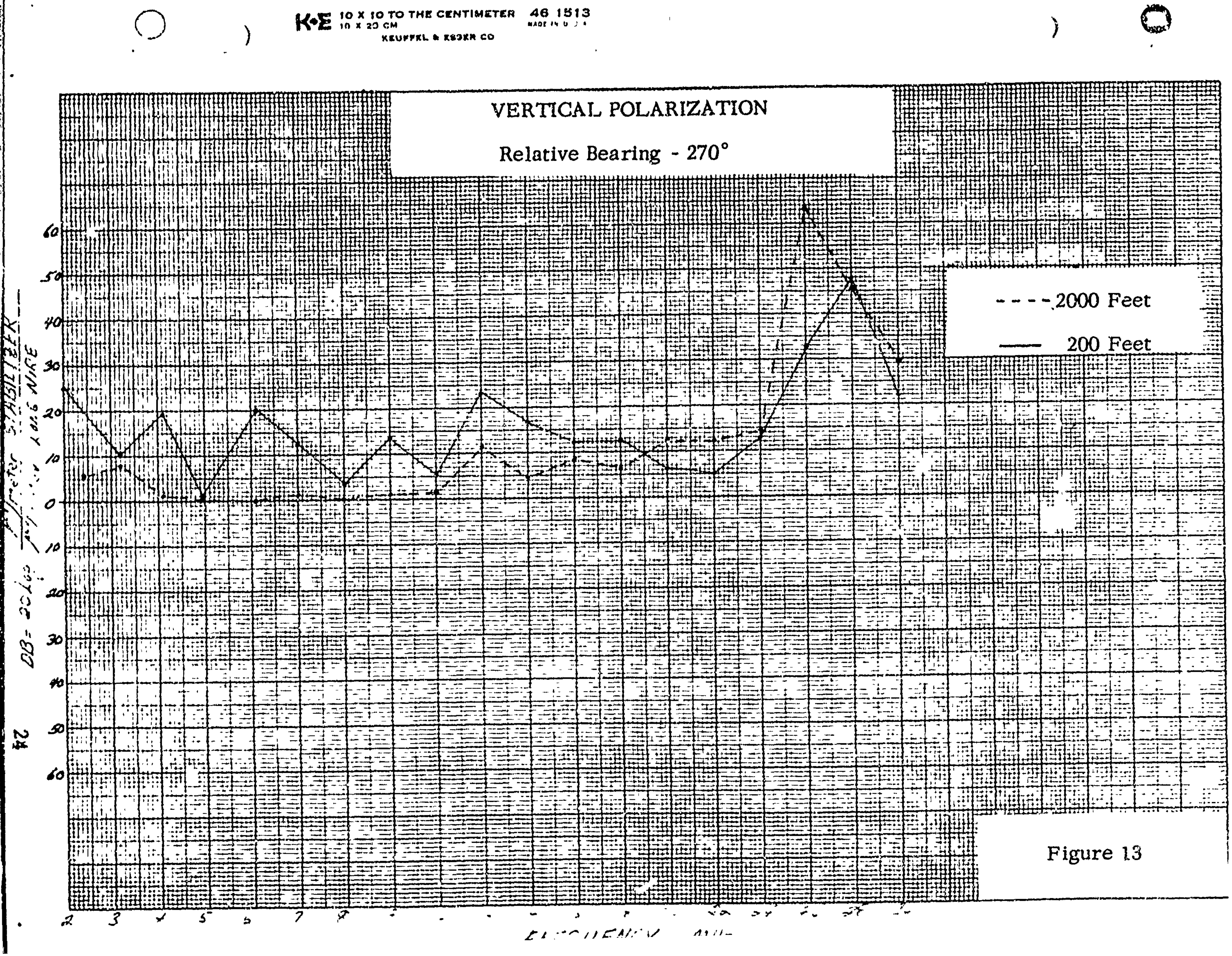

K•E 10 X 10 TO THE CENTIMETER 46 1513
10 X 25 CM
KEUFFEL & ESSER CO
VERTICAL POLARIZATION
Relative Bearing - 270°
- - - - 2000 Feet
—— 200 Feet
60
50
40
30
20
10
0
10
20
30
40
50
60

Figure 13

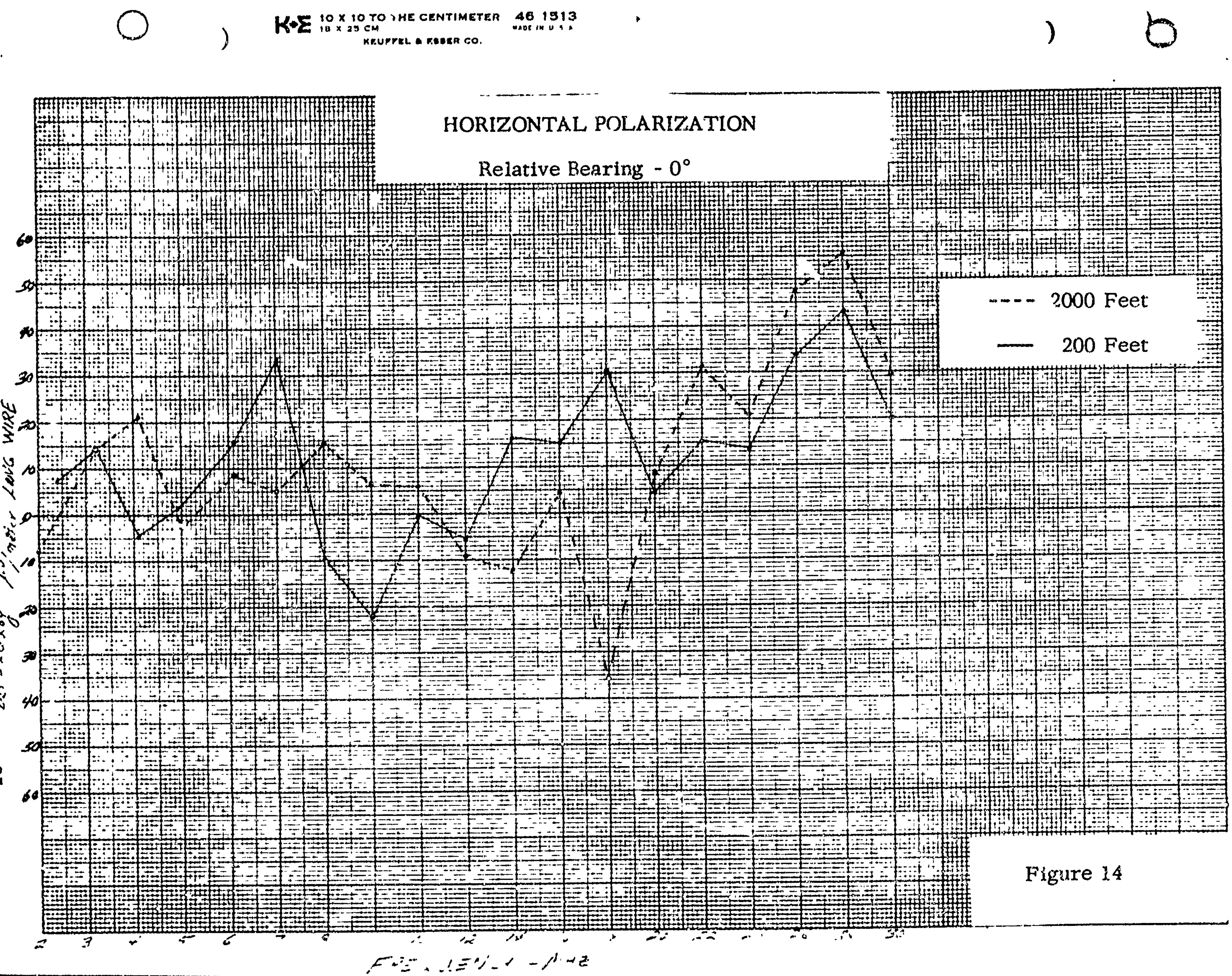

HORIZONTAL POLARIZATION
Relative Bearing - 0°
2000 Feet
200 Feet
60
50
40
30
20
10
0
10
20
30
40
50
60

Figure 14

K+E 10 X 10 TO THE CENTIMETER 46 1513
10 X 25 CM
KEUFFEL & ESSER CO.

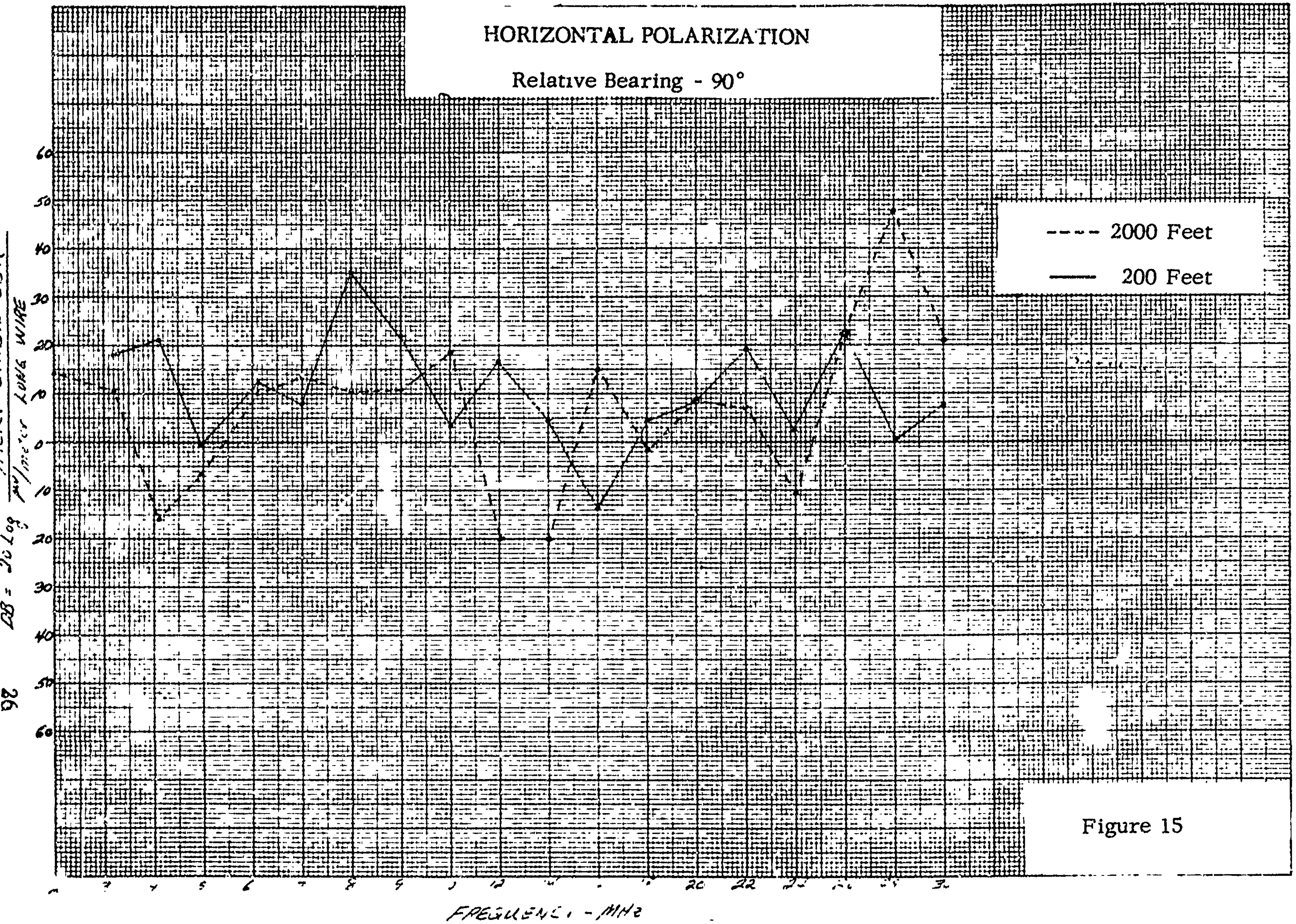


Figure 15

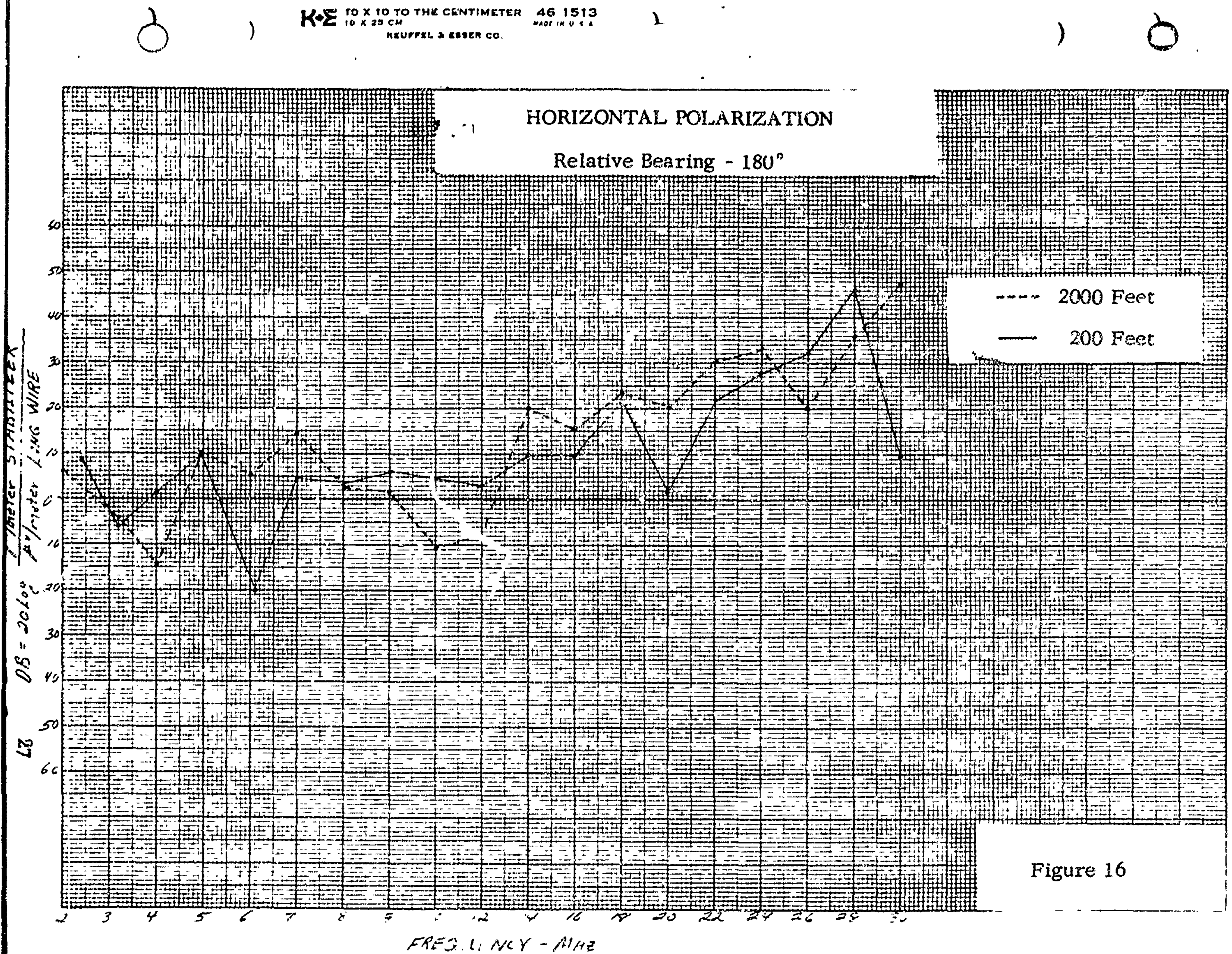

K+E 10 X 10 TO THE CENTIMETER 46 1513
10 X 25 CM MADE IN U.S.A.
KEUFFEL & ESSER CO.
HORIZONTAL POLARIZATION
Relative Bearing - 180°
2000 Feet
200 Feet
DB = 20log $\frac{\mu v/\text{meter STABILIZER}}{\mu v/\text{meter LONG WIRE}}$
FREQUENCY - MHz

Figure 16

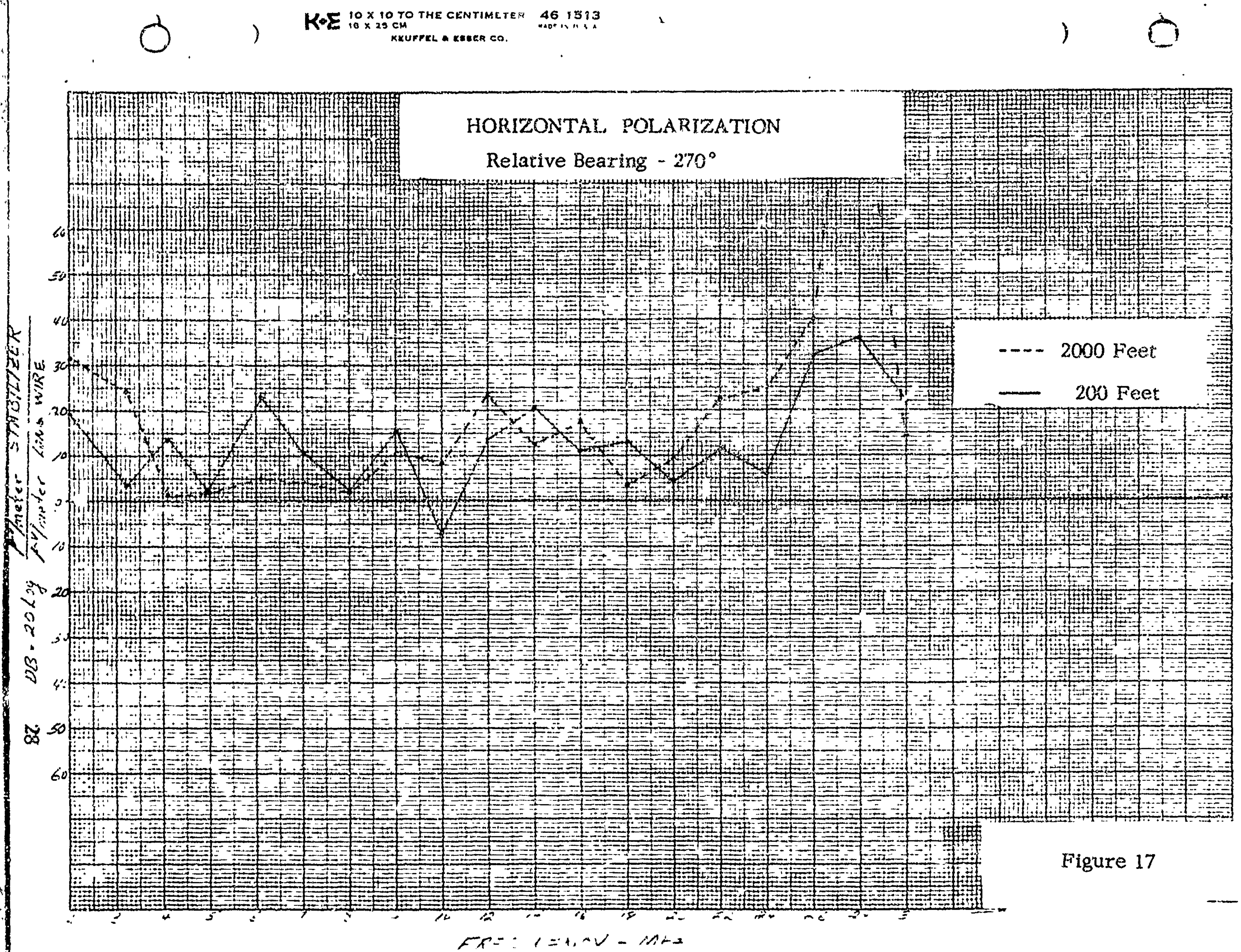

K+E 10 X 10 TO THE CENTIMETER 46 1513
10 X 25 CM
KEUFFEL & ESSER CO.
HORIZONTAL POLARIZATION
Relative Bearing - 270°
---- 2000 Feet
—— 200 Feet
60
50
40
30
20
10
0
10
20
50
60

Figure 17

LIST OF TABLES

TABLE 1

IMPEDANCE OF HORIZONTAL STABILIZER ANTENNA

FREQUENCY-MHz	IMPEDANCE	FREQUENCY-MHz	IMPEDANCE
2.0	4.45-j600	15.0	7.5-j36.7
2.5	4.9-j480	16.0	13.3-j25
3.0	6.6-j383	17.0	21.0-j11.75
4.0	24.0-j275	18.0	33.0-j2.78
5.0	29.0-j240	19.0	53.0-j3.95
6.0	17.0-j200	20.0	60.0-j10
7.0	12.5-j164	21.0	47.5-j16.6
7.5	18.0-j156	22.0	43.0-j19.3
8.0	18.1-j144	23.0	40.0-j17.4
8.6	13.4-j128	24.0	34.0-j12.5
9.0	13.2-j122	25.0	47.0-j0
10.0	11.0-j105	26.0	46.9+j8.65
11.0	9.5-j90	27.0	56.0+j11.1
12.0	9.1-j83	28.0	70.0-j3.2
13.0	8.1-j75	29.0	67.0-j13.8
14.0	7.6-j53.6	30.0	60.0-j23.3

TABLE 1

IMPEDANCE OF HORIZONTAL STABILIZER ANTENNA

FREQUENCY-MHz	IMPEDANCE	FREQUENCY-MHz	IMPEDANCE
2.0	4.45-j600	15.0	7.5-j36.7
2.5	4.9-j480	16.0	13.3-j25
3.0	6.6-j383	17.0	21.0-j11.75
4.0	24.0-j275	18.0	33.0-j2.78
5.0	29.0-j240	19.0	53.0-j3.95
6.0	17.0-j200	20.0	60.0-j10
7.0	12.5-j164	21.0	47.5-j16.6
7.5	18.0-j156	22.0	43.0-j19.3
8.0	18.1-j144	23.0	40.0-j17.4
8.6	13.4-j128	24.0	34.0-j12.5
9.0	13.2-j122	25.0	47.0-j0
10.0	11.0-j105	26.0	46.9+j8.65
11.0	9.5-j90	27.0	56.0+j11.1
12.0	9.1-j83	28.0	70.0-j3.2
13.0	8.1-j75	29.0	67.0-j13.8
14.0	7.6-j53.6	30.0	60.0-j23.3

TABLE 2

VSWR AND FEED POINT CURRENT

FREQUENCY-MHz	POWER - WATTS FORWARD	REFLECTED	VSWR	FEED POINT CURRENT AMPS
2.0	150	0.1	1.05:1	4.0
2.5	140	0.1	1.05:1	4.0
3.0	140	0.15	1.07:1	3.8
4.1	130	1.4	1.23:1	2.3
4.95	130	1.1	1.2:1	1.5
5.2	125	0.4	1.12:1	2.0
6.0	120	0	1:1	2.0
7.0	120	0.1	1.06:1	2.4
7.5	120	0.15	1.02:1	2.8
8.0	125	0.3	1.1:1	3.0
8.6	120	0.1	1.06:1	3.2
9.0	110	0	1:1	3.2
10.0	120	0.1	1.06:1	3.3
11.0	125	0.2	1.08:1	3.4
12.0	110	0.1	1.06:1	3.2
13.0	110	0	1:1	3.2
14.0	120	0.1	1.06:1	3.1
15.0	120	0.1	1.06:1	3.45
16.0	110	0	1:1	3.0
17.0	125	0.1	1.06:1	2.8

TABLE 2
(Continued)

FREQUENCY-MHz	POWER - WATTS FORWARD	POWER - WATTS REFLECTED	VSWR	FEED POINT CURRENT AMPS
18.0	120	0	1:1	2.4
19.0	110	0	1:1	2.0
20.0	120	0.1	1.06:1	1.9
21.0	115	0	1:1	1.9
22.0	110	0	1:1	1.6
23.0	115	0.1	1.06:1	1.5
24.0	120	0.15	1.07:1	1.4
25.0	110	0	1:1	1.3
26.0	110	0.1	1.06:1	1.5
27.0	120	0.9	1.19:1	1.5
28.0	110	0.2	1.09:1	1.5
29.0	100	0.1	1.06:1	1.5
30.0	110	0.95	1.2:1	1.5

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TABLE 3

UNIVAC COUPLER. TYPE 3461 A1
PERFORMANCE DATA ON SIMULATED CH-53 ANTENNA

FREQUENCY	ANTENNA Z	VSWR	TUNE TIME	EFFICIENCY
2 Mhz	4.45-j600	1.15	6.5 sec.	38%
2.5	4.9-j480	1.08	5.6	45
3	6.6-j383	1.02	4.7	62
4	24-j275	1.06	3.8	86
5	29-j240	1.05	3.5	89
6	17-j200	1.16	3.2	83
7	12.5-j164	1.07	3.2	85
8	18-j144	1.15	3.0	87
9	13.2-j122	1.14	3.1	78
10	11-j105	1.16	3.4	70
11	9.5-j90	1.10	3.3	72
12	9.1-j83	1.16	3.4	70
13	8.1-j75	1.11	3.2	70
14	7.6-j53	1.15	3.0	69
15	7.5-j36	1.17	2.8	68
16	13.3-j25	1.19	2.2	76
17	21-j11.75	1.18	2.1	85
18	33-j3	1.2	2.0	above 90
19	53-j3.95	1.15	1.9	above 90

TABLE 3
(Continued)

FREQUENCY	ANTENNA Z	VSWR	TUNE TIME	EFFICIENCY
20	60-j10	1.21	2.1	above 90
21	48-j17	1.18	2.0	above 90
22	43-j20	1.24	2.2	above 90
23	40-j17	1.2	2.1	above 90
24	34-j12	1.27	2.0	above 90
25	47-j0	1.18	1.9	above 90
26	47+j8	1.24	1.7	above 90
27	56+j12	1.25	1.8	above 90
28	70-j3.2	1.30	1.9	above 90
29	67-j14	1.28	1.7	above 90
30	60-j24	1.28	1.5	above 90

NOTE: This is a direct copy of the information received from UNIVAC.

TABLE 4

VERTICAL FIELD INTENSITY IN MICROVOLTS PER METER AT ZERO DEGREES

	200 Feet			2000 Feet		
Frequency-MHz	Stabilizer	Wire	DB	Stabilizer	Wire	DB
2.0				296,000	26,000	21.06
2.4	10,000	2,400	12.4			
3.2	40,000	2,600	23.74	>313,000	234,000	2.25
4.1	2,000	3,800	-5.58	142,300	60,000	7.5
4.95	60,000	20,000	9.54	360,000	240,000	3.52
6.1	42,000	15,000	8.94	922,000	264,400	10.85
7.02	30,000	2,000	23.56	572,000	694,000	-1.68
7.85	20,000	14,000	3.1	353,000	235,500	3.54
9.0	3,600	60,000	-24.44	443,000	320,000	2.82
10.05	16,000	35,000	-7.8	32,100	30,450	0.48
12.0	20,000	18,000	0.9	548,000	285,500	5.67
13.99	35,000	4,000	18.84	107,500	10,750	20.0
15.99	7,000	3,000	7.36	218,500	136,600	4.08
17.95	12,000	3,200	11.48	33,400	66,700	-6.02
20.1	>4170	1,666	7.96	75.1	24.2	9.48
22.0	>4650	930	13.98	837	85.7	19.8
24.0	>5000	2750	5.2	1050	115	19.2
26.0	>5410	406	22.5	1243	23.8	35.6
28.0	>5880	118	33.98	1000	1.58	56.2
29.999	>6250	5940	0.44	1626	40.7	32.0

TABLE 5

VERTICAL FIELD INTENSITY IN MICROVOLTS PER METER AT NINETY DEGREES

	200 Feet			2000 Feet		
Frequency-MHz	Stabilizer	Wire	DB	Stabilizer	Wire	DB
2.4	60,000	4,000	23.52	1,000,000	180,000	-14.9
3.2	120,000	10,000	21.6	>312,000	190,000	4.3
4.1	100,000	7,000	23.12	72,000	>200,000	-9.12
4.95	60,000	70,000	-1.34	120,000	>200,000	-4.44
6.1	100,000	30,000	10.18	463,000	140,000	10.4
7.02	60,000	20,000	9.54	878,000	110,000	18.29
7.85	100,000	1,400	37.0	824,000	150,000	14.8
9.0	100,000	10,000	20.0	800,000	60,000	22.5
10.05	10,000	6,000	4.44	87,000	70,000	1.88
12.0	40,000	4,000	20.0	329,000	104,000	10.0
13.99	20,000	5,000	12.0	107,500	130,000	-1.7
16.09	4,000	8,000	-6.02	410,000	40,000	20.2
17.95	5,000	7,000	-2.52	16,500	4,000	12.3
20.1	1,250	938	2.5	17.9	54.2	-9.6
22.0	1,395	466	9.5	60.5	60.5	0
24.0	1500	650	.7.24	110	27.0	12.18
26.0	>2,700	216	21.94	865	135.0	16.1
28.0	> 2,940	88.3	30.44	1176	39.4	29.5
29.99	> 3,120	1,875	4.44	1250	45.0	28.9

TABLE 6

VERTICAL FIELD INTENSITY IN MICROVOLTS PER METER AT ONE HUNDRED EIGHTY DEGREES

	200 Feet			2000 Feet		
Frequency-MHz	Stabilizer	Wire	DB	Stabilizer	Wire	DB
2.4	30,000	8,000	11.48	>200,000	>200,000	0
3.2	8,000	16,000	-6.02	>200,000	190,000	0.44
4.1	40,000	35,000	1.16	190,000	160,000	1.5
4.95	140,000	80,000	4.86	180,000	150,000	1.58
6.1	2,400	32,000	-22.5	160,000	120,000	2.5
7.02	35,000	12,000	9.3	164,000	90,000	5.23
7.85	1,400	10,000	-17.08	136,000	100,000	2.66
9.0	1,400	10,000	-17.08	120,000	60,000	6.2
10.05	10,000	20,000	-6.1	80,000	56,000	3.08
12.0	20,000	12,000	4.44	80,000	110,000	-2.76
13.99	6,000	5,000	1.58	150,000	40,000	11.58
15.99	4,000	4000	0	60,000	14,000	12.64
17.95	40,000	6000	16.48	52,000	7,000	17.49
20.1	>2080	584	11.04	116.8	39.5	9.42
22.0	>2330	395	15.42	381	41.8	19.18
24.0	>2500	550	14.64	800	80	20.0
26.0	>2700	86.5	30.68	1190	35.1	30.6
28.0	>2940	53	34.88	1178	25.9	33.16
29.99	>3130	812	11.7	593	15.6	31.6

TABLE 7

VERTICAL FIELD INTENSITY IN MICROVOLTS PER METER AT TWO HUNDRED SEVENTY DEGREES

	200 Feet			2000 Feet		
Frequency-MHz	Stabilizer	Wire	DB	Stabilizer	Wire	DB
2.4	50,000	2,800	25.06	>200,000	106,000	5.5
3.2	12,000	3,600	10.46	>200,000	80,000	7.96
4.1	30,000	3,200	19.44	180,000	160,000	1.02
4.95	120,000	160,000	1.58	190,000	180,000	0.48
6.1	140,000	14,000	20.0	180,000	180,000	0
7.02	60,000	14.000	12.64	194,000	170,000	1.13
7.85	60,000	40,000	3.52	>200,000	>200,000	0
9.0	60,000	12,000	13.98	160,000	140,000	1.16
10.05	18,000	10,000	5.1	120,000	100,000	1.58
12.0	20,000	1,400	23.1	90,000	24,000	11.48
13.99	25,000	3,600	16.84	150,000	86,000	4.84
15.99	20,000	5,000	12.04	80,000	30,000	8.52
17.95	42,000	10,000	12.46	30,000	14,000	6.62
20.1	>4[illegible]70	2000	6.38	250	58.4	12.62
22.0	>4650	232 5	6.0	312	74.4	12.45
24.0	>5000	1125	12.94	500	95.0	14.42
26.0	>5410	124.2	32 78	2130	14.1	63.58
28.0	>5880	23.5	47.98	942	5.0	45.5
29.99	>6250	469	22.5	1124	37.5	29.54

TABLE 8

HORIZONTAL FIELD INTENSITY IN MICROVOLTS PER METER AT ZERO DEGREES

Frequency-MHz	200 Feet Stabilizer	200 Feet Wire	DB	2000 Feet Stabilizer	2000 Feet Wire	DB
2.4	2,400	1,000	7.6	86,400	133,000	-7.84
3.2	7,000	1,350	14.28	>134,900	26,500	14.12
4.1	1,500	2,500	-4.44	284,000	24,800	21.18
4.95	20,000	16,000	1.94	120,000	164,500	-2.72
6.1	30,000	5,000	15.56	329,000	123,400	8.55
7.02	38,000	800	33.52	>1,422,000	800,000	5.0
7.85	3,200	10,000	-9.9	>2,090,000	353,000	15.4
9.0	1,400	18,000	-22.18	200,000	93,400	6.64
10.05	3,500	3,600	-0.24	21,400	10,710	6.02
12.0	2,600	5,000	-5.68	15,820	45,300	-9.14
13.99	13,000	2,000	16.22	200,000	800,000	-12.04
15.99	10,000	1,200	15.32	41,820	24,800	4.54
17.95	20,000	600	30.46	6,670	400,000	-35.6
20.1	2,080	2,500	-4.44	166.7	62.5	8.56
22.0	>4,650	7[illegible]	15.38	251	7.44	31.1
24.0	>5000	1,000	13.98	360	32.0	21.0
26.0	>5410	108	34.32	330	1.62	47.8
28.0	>5880	41	43.1	548	0.88	55.9
29.99	>6250	625	20.0	1000	33.7	29.46

TABLE 9

HORIZONTAL FIELD INTENSITY IN MICROVOLTS PER METER AT NINETY DEGREES

	200 Feet			2000 Feet		
Frequency-MHz	Stabilizer	Wire	DB	Stabilizer	Wire	DB
2.4	28,000	1,400	60.0	863,000	166,600	14.32
3.2	26,000	3,200	18.2	>757,000	227,000	10.46
4.1	30,000	2,600	21.24	102,000	637,000	-15.92
4.95	18,000	20,000	-0.92	197,000	461,000	-7.4
6.1	40,000	10,000	12.04	77,800	24,500	10.0
7.02	15,000	6,000	7.96	1,305,000	214,000	13.72
7.85	40,000	700	35.14	765,000	235,000	10.2
9.0	50,000	3,800	22.38	346,000	25,700	10.9
10.05	1,600	2,400	-3.52	21,400	2,570	18.64
12.0	18,000	2,600	16.82	18,100	181,000	-20.0
13.99	7,000	4,000	4.86	171,500	2,000,000	-20.56
16.09	1,200	6,000	-13.98	24,800	4,370	15.08
17.95	2,000	1,200	4.44	3,330	4,000	-1.6
20.1	1,667	625	8.52	175	62.5	8.9
22.0	2,160	221	19.8	148.8	65.2	7.12
24.0	2,125	1625	2.34	27.0	90.0	-10.46
26.0	1,620	121.5	22.48	270	17.3	23.86
28.0	>2,940	2,790	0.46	471	1.88	47.98
29.99	>3,120	1,250	7.96	1000	87.5	21.14

TABLE 10

HORIZONTAL FIELD INTENSITY IN MICROVOLTS PER METER AT ONE HUNDRED EIGHTY DEGREES

	200 Feet			2000 Feet		
Frequency-MHz	Stabilizer	Wire	DB	Stabilizer	Wire	DB
2.4	10,000	3,800	8.4	1,000,000	500,000	6.0
3.2	3,000	6,000	-6.0	530,000	606,000	-4.2
4.1	14,000	12,000	1.34	126,000	638,000	-14.12
4.95	60,000	20,000	9.54	1,130,000	329,000	10.72
6.1	700	7,000	-20.0	>412,000	222,000	5.36
7.02	14,000	8,000	4.86	1,280,000	240,000	14.54
7.85	9,000	6,000	3.52	706,000	530,000	2.49
9.0	12,000	6,000	6.02	66,700	53,300	1.92
10.05	6,000	10,000	4.44	38,500	128,500	-10.54
12.0	10,000	7,000	3.1	18,100	45,200	-7.96
13.99	6,000	1,900	9.98	572,000	57,200	20.0
15.99	2800	900	9.86	7,950	1,322	15.58
17.95	25,000	2000	21.6	40,900	2,770	23.42
20.1	>2030	1665	1.92	392	33.3	21.42
22.0	>2330	186	21.98	340	10.2	30.44
24.0	>2500	100	27.96	340	7.5	33.12
26.0	>2700	67.6	32.02	1080	10.8	20.0
28.0	>2940	13.2	46.96	1590	23.5	36.6
29.99	>3130	1094	9.12	2500	10.6	47.44

TABLE II
HORIZONTAL FIELD INTENSITY IN MICROVOLTS PER METER AT TWO HUNDRED SEVENTY DEGREES

Frequency MHz	200 Feet Stabilizer	200 Feet Wire	DB	2000 Feet Stabilizer	2000 Feet Wire	DB
2.0	11,000	1,200	19.24	3,330,000	93,800	31.1
3.2	2,400	1,600	3.52	1,220,000	75,700	24.24
4.1	6,000	1,200	13.98	163,600	141,800	1.26
4.93	40,000	30,000	2.5	329,000	263,000	1.98
6.1	40,000	2,800	23.1	> 412,000	222,000	5.36
7.02	20,000	6,000	10.46	400,000	240,000	4.44
7.85	18,000	13,000	2.82	588,000	471,000	1.94
9.0	30,000	5,000	15.58	186,600	53,300	10.9
10.05	2,600	6,000	-7.26	85,600	32,200	8.48
12.0	3,000	600	13.98	67,800	4,530	23.56
13.99	10,000	900	20.9	371,000	171,500	12.7
15.99	3,200	1,600	6.02	12,400	1,652	17.52
17.95	14,000	3,000	13.38	8,000	5,330	3.56
20.1	1770	1042	4.6	179.2	62.5	9.14
22.0	1745	465	11.48	148.9	11.2	22.46
24.0	1250	625	6.02	235.0	13.0	25.14
26.0	2013	48.7	32.32	367.8	3.52	40.36
28.0	>5880	88.2	36.48	470.0	*	-----
29.99	>6250	469	22.48	312.0	60.0	14.32

* No readable field intensity was obtained.

TABLE 12

UNIVAC 3461-A1 ANTENNA COUPLER EFFICIENCY

	Calculated		Measured	
Frequency-MHz	Efficiency-%(1)	Antenna Current-Amps	Efficiency-%(2)	Antenna Current-Amps
2.0	62	3.58	38	4.0
2.5	68	3.59	45	4.0
3.0	75.3	3.62	62	3.8
4.0	86	2.16	86	2.3
5.0	87	1.99	89	1.5
6.0	86	2.42	83	2.0
7.0	85.5	2.85	85	2.4
8.0	86.5	2.46	87	3.0
9.0	86	2.7	78	3.2
10.0	86	2.76	70	3.3
11.0	86	3.08	72	3.4
12.0	[illegible]	3.09	70	3.2
13.0	[illegible]	3.09	70	3.2
14.0	87	3.3	69	3.1
15.0	88	3.3	68	3.45

TABLE 12
(Continued)

	Calculated		Measured	
Frequency-MHz	Efficiency-%(1)	Antenna Current-Amps	Efficiency-%(2)	Antenna Current-Amps
16.0	89	2.5	76	3.0
17.0	90	2.25	85	2.8
18.0	90	1.8	90	2.4
19.0	90	1.35	90	2.0
20.0	90	1.34	90	1.9
21.0	90	1.47	90	1.9
22.0	90	1.52	90	1.6
23.0	90	1.61	90	1.5
24.0	90	1.78	90	1.4
25.0	90	1.59	90	1.3
26.0	90	1.59	90	1.5
27.0	90	1.39	90	1.5
28.0	90	1.19	90	1.5
29.0	90	1.16	90	1.5
30.0	90	1.28	90	1.5

TABLE 12
(Continued)

NOTE (1) Efficiency was calculated using approximate formula provided by Univac:

$$\% \text{ Efficiency} = \frac{90}{1 + \frac{QA}{QL}}$$

Where QA = Antenna Q
QL = 300 (2-4 MHz)
250 (4-8 MHz)
200 (8-16 MHz)
150 (16-30 MHz)

NOTE (2) Measured efficiency is taken from Table 3.

TEST EQUIPMENT

Name	Model No.	Manufacture	S/N	Accuracy
Signal Generator	606A	Hewlett-Packard	301-04307	±1%
Field Intensity Meter	32A	Ferris	614	±15%
Field Intensity Meter	32B	Ferris	745	±15%
Field Intensity Meter	58AS	Measurements Corp.	831	±20%
R. F. Bridge	1606A	General Radio	1452	2%
R. F. Ammeter	1339C	Simpson	-----	2% F.S.
Fwd. and Ref. Power Meter	263.3	M. C. Jones	C-6107	5% F.S.
Wheatstone Bridge	5305	Leeds & Northrup	1674195	±0.15%

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13. ABSTRACT

This report presents the results of work accomplished on contract N62269-67-C-0190, Feasibility Study of the CH-53A Horizontal Stabilizer as an HF antenna. Ground tests, conducted on a bailed CH-53A BuNo. 152396, indicate that performance of the HF communication system with an isolated stabilizer antenna provides an improved communications capability for the CH-53A helicopter.

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	ROLE	WT	ROLE	WT	ROLE	WT
HELICOPTER HF ANTENNA HORIZONTAL STABILIZER RADIATION PATTERN						

APPENDIX I

POWER DISSIPATION IN DIELECTICS

From Reference (7), Page 323.

Where $\cos\theta = 0.0184$ = Dissipation Factor

$\epsilon = \epsilon_r \epsilon_0$

$\epsilon_0 = 8.85 \times 10^{-12}$

$\epsilon_r = 4.27$ = Dielectric Constant

$\omega = 2\pi f$

$A = 45.3\ in^3$

$$\sigma' = \omega \epsilon \cos\theta$$

$$W = \frac{E^2 \sigma' A}{6.1 \times 10^4\ in^3}$$

Condition I Assume f = 2 MHz E = 10 Kv

$$\epsilon = 8.85 \times 10^{-12} \times 4.27 = 37.7 \times 10^{-12}$$
$$\sigma' = 12.58 \times 10^6 \times 37.7 \times 10^{-12} \times 18.4 \times 10^{-3} = 8.72 \times 10^{-6}$$

$$W = \frac{(10 \times 10^3)^2 (8.27 \times 10^{-6}) (45.3)}{6.1 \times 10^4} = 0.64 \text{ watts.}$$

Condition II Assume f = 30 MHz E = 10 Kv

$$\epsilon = 1.885 \times 10^8 \times 3.77 \times 10^{-11} \times 1.84 \times 10^{-2} = 13.08 \times 10^{-5}$$

$$W = \frac{(10 \times 10^3)^2 (13.08 \times 10^{-5}) (45.3)}{6.1 \times 10^4} = 9.72 \text{ watts.}$$

NOTE: Condition I and II represent the maximum power loss possible as 10 kilovolts is the maximum rated stress of the components within the system.